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Performance of Some Faba bean Genotypes for Tolerance to the Infestation of Broomrape (Orobanche crenata) Weed

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Abstract

A field experiment was conducted at the Agricultural Research Farm at Al-Kawthar site, Faculty of Agriculture, Sohag University, Egypt, during the 2018/19 season, to evaluate 10 faba bean genotypes as well as their morphological and anatomical root traits to determine the genotype that is the most tolerant of *Orobanche* infection under naturally infested soil conditions. Randomized complete blocks design (RCBD) in a plots arrangement with three replicates was used. The experiment included 10 faba bean genotypes (Sakha 1, Giza 843, Giza 716, Nubaria 1, Misr 3, Assiut 62, Assiut 85, Assiut 115, Assiut 125 and Assiut 215). The results revealed that the genotypes Giza 843 and Misr 3 were more tolerance to broomrape than other genotypes and recorded the lowest values for the number of broomrape (spikes/m^2) and the dry weight of broomrape spikes (g/m^2). Furthermore, genotypes Giza 843 and Misr 3 produced the highest biological yield and seed yield (ton/fed) under these conditions. While Nubaria 1 and Giza 716 genotypes were highly susceptible to broomrape infection and recorded the highest values for the number of broomrape (spikes/m^2) and the dry weight of broomrape spikes (g/m^2), they also gave the lowest values for the biological yield and seed yield (ton/fed) under these conditions. Correlation analysis among the studied traits also showed that the root length was positively, significantly and strongly correlated with biological yield and seed yield (ton/fed). On the other hand, the root length was negatively, highly significantly and strongly correlated with the number of broomrape and the dry weight of broomrape spikes. The fresh weight of root was positively, highly significantly and strongly correlated with the number of broomrape and the dry weight of broomrape spikes. While, the fresh weight of root was negatively, highly significantly and strongly correlated with biological yield and seed yield (ton/fed). These findings suggest that the vascular system of cultivars Giza 843 and Misr 3 root cells played a significant role in the tolerance of broomrape infestation compared to other susceptible genotypes to broomrape infection, such as genotype Giza 716 and the highly susceptible genotype Nubaria 1. Finally, it can be concluded that many defense mechanisms have been detected in faba bean plants that tolerate broomrape attack, mainly involving cell wall reinforcement and stamping of vascular tissues with a decrease in the secretion of germ stimulants.

INTRODUCTION

Faba bean is one of the most essential winter legume crops for human nutrition in Egypt. About 58 % of the seeds' weight is made up of carbohydrates, which are regarded as a good source of energy. Seeds are a low-cost protein source for a large portion of the population because they contain between 24 and 35 % protein. Production of faba bean in Egypt is still limited and declining according to FAO statistics, the cultivated area of faba bean in 2005 was (198.166 fed) produced (281.650 tons) but it was in 2020 (58.120 fed) produced (88.109 tons). The considerable decline was a result of susceptibility to foliar diseases such as chocolate spots, insect pests, and the effects of parasitic weeds such as broomrape. Broomrape (*Orobanche crenata*) is an annual plant that is obligatory parasitic on the secondary roots of faba bean plants and other susceptible hosts in Egypt and is also extensively dispersed in the Mediterranean region. It causes significant losses to the host and, in severe cases, may result in crop failure. The amount of yield loss changes based on host genotype, parasitism level and a variety of other factors. Most crops have few options for broomrape management because of the complexity of mechanical control and a lack of dependable, selective herbicides. Faba bean genotypes are markedly different in their ability to tolerate broomrape infection. It could be observed that the tolerance cultivars may provide better protection against broomrape parasitism, in addition to their differences in the growth characteristics, potential yield, and yield components such as the number of pods/plant and seed yield/fed. Several studies have been conducted on this subject, Abou-Raya *et al.* (1973) indicated that the germination stimulants are firstly secreted by the host root just before its flowering stage and continued during the flowering period and are only effective on the parasite seed, within a distance of 3-4 mm of the host root. Therefore, the *Orobanche* seeds laid within a few millimeters of the host root connected with the concentrations of exuded stimulants will only germinate. Mesa-García and García-Torres (1984) stated that the broomrapes are parasitic leafless plants that contain self-pollinating flowers and attack the roots of a considerable number of cultivated crops, especially faba bean, other food legumes and a wide range of vegetables. Each adult *Orobanche crenata* weed may produce thousands of seeds, approximately 500,000 per flower spike, with a dormancy of 10 years or more. Gutierrez II (2001) showed that *Orobanche* parasitism affected faba bean productivity, such as seed yield and harvest index, The effect was approximately a 5% yield reduction in the vitro greenhouse experiments, whereas it was in the range of 0 to 100% yield losses reported in the field studies. El-Ghareib *et al.* (2019) revealed the superiority of Giza 843 and Misr 3 cultivars on Nubaria 1 in the most studied traits: plant height (cm), number of pods/plant, biological yield (kg/fed), seed yield (kg/fed) and harvest index percentage. Cultivars Giza 843 and Misr 3 recorded the lowest values of broomrape infestation percentage per plot compared with the Nubaria 1 cultivar. Aalders and Pieters (1986) noticed that the higher number of *Orobanche* tubercles at a more advanced stage of development were supported by faba bean cultivars that have higher root and shoot biomass. Pérez-de-Luque *et al.* (2007) observed that the accumulation of callose around the penetration pathway of the parasite is a key feature associated with the major mechanism responsible for stopping parasite penetration into the host cortex. In conclusion, stoppage of *Orobanche crenata* seedling penetration into the host root is a quantitative response in faba bean and is associated with reinforcement of host cell walls in contact with the parasite intrusive cells. Abdel-Wahab and Eman (2021) reported that the vascular system in faba bean root cells can play an important role in the tolerance of broomrape infestation. Before broomrape infestation, the root cells of Nubaria 1 or Nubaria 2 cultivars contained interstitial spaces that allowed the passage of water, nutrients and metabolites to the different parts of the plant with no negative effect on the vascular cylinder (xylem and phloem; transport vessels). Meanwhile, the infestation with broomrape increased the thickness of the root cell wall of the cultivar Nubaria 2 and almost completely closed the interstitial spaces of its root (stamping) to prevent the translocation of water and photosynthesis products from the plant to the parasite. These results indicate that the vascular system of cultivar Nubaria 2 root cells played a major role in the tolerance of broomrape infestation than the Nubaria 1 cultivar. Several pleading mechanisms have been reported to tolerate broomrape infestation, mainly including cell wall build-up and stamping of vascular tissues. The goal of this study was to evaluate some faba bean genotypes as well as their morphological and anatomical root traits to determine the genotype that is the most tolerant of *Orobanche* infection that could lead to better broomrape control and enhance the productivity of the faba bean crop under these conditions.

MATERIALS AND METHODS

A field experiment was carried out at the Agricultural Research Farm at Al-Kawthar site, Faculty of Agriculture, Sohag University, Egypt, during the season of 2018/19. This study aimed to evaluate some faba bean genotypes as well as their morphological and anatomical root traits to determine the genotype that is the most tolerant of *Orobanche* infection under naturally infested soil conditions. The experiment included 10 treatments, which were ten faba bean genotypes.

Treatments: 10 different genotypes of faba bean.

Faba bean genotypes	1- Sakha 1= (G1)	6- Assiut 62= (G6)
	2- Giza 843= (G2)	7- Assiut 85= (G7)
	3- Giza 716= (G3)	8- Assiut 115= (G8)
	4- Nubaria 1= (G4)	9- Assiut 125= (G9)
	5- Misr 3= (G5)	10- Assiut 215= (G10)

Randomized Complete Blocks design in a plots arrangement with three replicates was used. The experimental plot area was 10.5 m^2 (4.4 m length and 2.4 m width), consisting of 4 ridges with 60 cm inter-row spacing. Planting faba bean seeds at 20 cm spacing on both sides of the ridge in alternative hills shape, which equivalent 140.000 plants/fed. Sowing date was on the 10^{th} of November, thinning was done overall plots after 1^{st} hoeing to remain the best two seedlings/hill. Other faba bean cultural practices were carried out according to the Egyptian Ministry of Agriculture's recommendations for faba bean production in this area.

Table (1): Soil properties of top-soil (0-30 cm) of the experimental site in 2018/19 season.

Soil properties	Gravel by weight (%)	Sand (%)	Silt (%)	Clay (%)	Soil texture
2018/19	11.20	42.51	29.80	27.69	CL

Data recorded

I. Growth characters: were measured on random sample of 10 guarded plants at 60 days from sowing.	**II. Yield and yield components:**	**III. Broomrape parasitic weeds**
	1. Biological yield (ton /fed).	1. Number of broomrape (spikes/m^2).
1. Plant height (cm).	2. Seed yield (ton/fed).	2. Dry weight of broomrape spikes (g/m^2).
2. Number of branches/plant.		
3. Root length (cm).	**IV.** The cross-sections of the secondary root cells for the faba bean genotypes : Collection and fixation of samples according to Pérez-de-Luque *et al.* (2005).	
4. Fresh weight of Root (g).		

Statistical analysis

The collected data were statistically analyzed according to Gomez and Gomez (1984) using Proc. GLM procedure (SAS version 9.1, SAS Institute 2003). The least significant difference (LSD) test at 5% level of probability was used for comparing among means of the 10 studied genotypes.

RESULTS AND DISCUSSION

The results of the growth traits, yield and its components of faba bean plants as affected by some faba bean genotypes under naturally infested soil conditions by (*Orobanche crenata Forsk*.) broomrape could be presented and discussed under the following topics:

I - Growth traits

1- Plant height (cm) at 60 days

Data presented in Table (2) revealed that faba bean genotypes had a highly significant effect on plant height (cm) at 60 days of age under naturally infested soil conditions by broomrape. It could be concluded that the tallest plants were recorded for genotype Giza 843, which recorded a plant height value of 92.83 cm at 60 days of age. The shortest plants were recorded for genotype Nubaria 1 which recorded a plant height value of 72.39 cm at 60 days of age. These results can be attributable to the behavior of the tested genotypes, which is governed by genetic constituents and their interaction with the environmental variables present during the growing season. Similar findings are in agreement with those obtained by Ghobashy (1997), Eid *et al.* (2017) and El-Ghareib *et al.* (2019).

2 - Number of branches/plant at 60 days

The data in the same Table (2) cleared that faba bean genotypes had a highly significant effect on the number of branches/plant at 60 days of age under naturally infested soil conditions by broomrape. It could be concluded that the highest values of the number of branches/plant were recorded for genotype Nubaria 1, which produced 4.15 branches at 60 days of age. While, the lowest value of the number of branches/plant was recorded for genotype Assiut 125, which produced 2.15 branches at 60 days of age. These results can be attributable to the behavior of the tested genotypes, which is governed by genetic constituents and their interaction with the environmental variables present during the growing season. These results took the same trend with those recorded by El-Ghareib *et al.* (2019).

3 - Root length (cm) at 60 days

Results in Table (2) showed that faba bean genotypes had a highly significant effect on the root length (cm) at 60 days of age under naturally infested soil conditions by broomrape. It could be noticed that genotype Giza 843 recorded the highest value of root length (cm) of 15.89 cm at 60 days of age. Otherwise, the lowest value of root length (cm) of 11.12 cm at 60 days of age was estimated with genotype Assiut 215. These results can be attributable to the behavior of the tested genotypes, which is governed by genetic constituents and their interaction with the environmental variables present during the growing season. These results were similar as recorded by Nassib *et al.* (1978) and Bayoumi *et al.* (2014).

4 - Fresh weight of Root (g) at 60 days

The results in Table (2) indicated that faba bean genotypes had a highly significant effect on the fresh weight of root (g) at 60 days of age under naturally infested soil conditions by broomrape. The heaviest fresh weight of root (g) of 83.96 g at 60 days of age was recorded for genotype Nubaria 1. While, the lowest value of the fresh weight of root (g) of 64.37 g at 60 days of age was recorded for genotype Giza 843. These results can be attributable to the behavior of the tested genotypes, which is governed by genetic constituents and their interaction with the environmental variables present during the growing season. Such results agree with those reported by Aalders and Pieters (1987).

II - Yield and its components

1 - Biological yield (ton/fed)

The data in Table (2) revealed that faba bean genotypes had a highly significant effect on the biological yield (ton/fed) of faba bean plants under naturally infested soil conditions by broomrape. The maximum value of the biological yield (ton/fed) of 3.639 tons was obtained from genotype Giza 843, followed by genotype Misr 3, which produced 3.590 tons. Whereas, the minimum values of the biological yield (ton/fed) of 1.495 tons and 1.707 tons were produced from Nubaria 1 and Giza 716 genotypes, respectively. These results can be attributable to the behavior of the tested genotypes, which is governed by genetic constituents and their interaction with the environmental variables present during the growing season. In addition, it could be observed that the tolerance genotypes may provide better protection against broomrape parasitism. The genotypes Giza 843 and Misr 3 showed markedly more tolerance to broomrape than other genotypes and gave the best values for the biological yield (ton/fed) under these conditions. While, genotype Nubaria 1 and genotype Giza 716 were highly susceptible to broomrape infection and gave the lowest values of the biological yield (ton/fed) under these conditions. These results agree with those reported by Megahed (1999), El-Degwy *et al.* (2010), Fernández-Aparicio *et al.* (2012), Soliman *et al.* (2012), Bayoumi *et al.* (2014), El-Ghareib *et al.* (2019) and Zeid and Mona (2019).

2 - Seed yield (ton/fed)

Results for the effect of faba bean genotypes on the seed yield (ton/fed) of faba bean plants under naturally infested soil conditions by broomrape are presented in Table (2). Analysis of variance showed a highly significant effect in the seed yield (ton/fed) of the faba bean plants due to the genotypes. It is clear that the seed yield (ton/fed) was significantly increased with genotypes Giza 843 and Misr 3. Genotype Giza 843 gave the highest seed yield (ton/fed) of 0.985 tons, followed by genotype Misr 3 which produced 0.964 tons/fed of seed yield. On the other hand, genotypes Nubaria 1 and Giza 716 recorded the lowest seed yield (ton/fed) of 0.176 tons and 0.244 tons, respectively. From the previous results, the genotypes Giza 843 and Misr 3 showed markedly more tolerance to broomrape than other genotypes and gave the best values for the seed yield (ton/fed) under these conditions. While, genotype Nubaria 1 and genotype Giza 716 were highly susceptible to broomrape infection and gave the lowest values of the seed yield (ton/fed) under these conditions. These results can be attributable to the behavior of the tested genotypes, which is governed by genetic constituents and their interaction with the environmental variables present during the growing season. In addition, it could be observed that the tolerance genotypes may provide better protection against broomrape parasitism. The resistance mechanisms of the faba bean genotypes may be due to the ability of these genotypes to effectively share in transmitting their properties of high yield and their immense ability to resist broomrape, reduce broomrape seed germination because of the low induction of seed germination by the roots of the host plant, which is a major component of resistance in these genotypes against the broomrape parasite and delayed broomrape attachment and late emergence above the soil surface allow these genotypes to avoid broomrape infection (Pérez-de-Luque *et al*., 2005, 2007 and 2010 and Fernández-Aparicio *et al*., 2012). For the previous reasons, the genotypes Giza 843 and Misr 3 have a low broomrape number (spikes/m^2) and the least amount of dry matter accumulated by the broomrape parasite. Therefore, their exposure to stress from the broomrape parasitic weeds is lower, allowing them to produce a better seed yield (ton/fed) under these conditions compared to other genotypes susceptible to broomrape infection. Similar results were also reported by Megahed (1999), El-Degwy *et al.* (2010), Soliman *et al.* (2012), Bayoumi *et al.* (2014), El-Ghareib *et al.* (2019) and Zeid and Mona (2019).

III - Broomrape parasitic weeds

1 - Number of broomrape (spikes/m^2)

The data recorded in the same Table (2) indicate clearly that, there was a highly significant effect in the number of broomrape (spikes/m^2) among faba bean genotypes under naturally infested soil conditions by broomrape. The highest mean values of the number of broomrape (spikes/m^2) of 66.50 spikes/m^2 and 61.00 spikes/m^2 were recorded with the Nubaria 1 and Giza 716 genotypes, respectively. However, the lowest mean values of the number of broomrape (spikes/m^2) were 17.00 spikes/m^2 and 18.50 spikes/m^2 obtained with the Giza 843 and Misr 3 genotypes, respectively. These results can be attributable to the behavior of the tested genotypes, which is governed by genetic constituents and their interaction with the environmental variables present during the growing season. In addition, it could be observed that the tolerance genotypes may provide better protection against broomrape parasitism. The genotypes Giza 843 and Misr 3 showed markedly more tolerance to broomrape than other genotypes. Such findings are in general agreement with those obtained by El-Ghareib et al. (2019).

2 - Dry weight of broomrape spikes (g/m^2)

Results presented in Table (2) show that the evaluated genotypes under naturally infested soil conditions by broomrape exhibited a highly significant effect in the dry weight of broomrape spikes (g/m^2). The heaviest dry weight of broomrape spikes (g/m^2) of 95.06 g/m^2 was recorded with genotype Nubaria 1, followed by genotype Giza 716 which recorded 94.67 g/m^2 of the dry weight of broomrape spikes. On the other hand, the least amount of dry weight of broomrape spikes (g/m^2) of 50.98 g/m^2 and 52.65 g/m^2 were recorded with the Giza 843 and Misr 3 genotypes, respectively. These results can be attributable to the behavior of the tested genotypes, which is governed by genetic constituents and their interaction with the environmental variables present during the growing season. In addition, it could be observed that the tolerance genotypes may provide better protection against broomrape parasitism. The genotypes Giza 843 and Misr 3 showed markedly more tolerance to broomrape than other genotypes and gave the lowest values for the number of broomrape (spikes/m^2) and the dry weight of broomrape spikes (g/m^2) under these conditions. While, genotype Nubaria 1 and genotype Giza 716 were highly susceptible to broomrape infection and gave the highest values of the number of broomrape (spikes/m^2) and the dry weight of broomrape spikes (g/m^2) under these conditions. Finally, we can conclude that the lower number and percentage of tubercles and the late establishment of the parasite on the tolerant genotype are probably due to the fact that the tolerance to broomrape is a multi-faceted response in faba bean and may include the presence of some other mechanical or chemical barriers in the host roots. Many defense mechanisms have been detected in faba bean plants that tolerate broomrape attack, mainly involving cell wall reinforcement and stamping of vascular tissues with a decrease in the secretion of germ stimulants. For the previous reasons, the genotypes Giza 843 and Misr 3 have a low broomrape number (spikes/m^2) and the least amount of dry matter accumulated by the broomrape parasite. Therefore, their exposure to stress from the broomrape parasitic weeds is lower, allowing them to produce the highest biological yield, seed yield and straw yield under these conditions compared to other genotypes susceptible to broomrape infection. Such findings are in general agreement with those obtained by Abbes *et al.* (2006), Pérez-de-Luque *et al.* (2010), El-Ghareib *et al.* (2019) and Zeid and Mona (2019).

IV - Correlation coefficient among the studied traits

Data in Table (3) show that plant height (cm) at 60 days was positively, highly significantly and strongly correlated with the root length (cm) at 60 days (0.59**), biological yield (ton/fed) (0.92**) and seed yield (ton/fed) (0.92**). While, plant height (cm) at 60 days was negatively, highly significantly and strongly correlated with the fresh weight of root (g) at 60 days (- 0.81**), the number of broomrape (spikes/m^2) (- 0.92**) and the dry weight of broomrape spikes (g/m^2) (- 0.93**), except that the number of branches/plant at 60 days (- 0.53*) was negatively, significantly and strongly correlated. As shown in Table (3) the number of branches/plant at 60 days was positively, highly significantly and strongly correlated with the fresh weight of root (g) at 60 days (0.71**) and the number of broomrape (spikes/m^2) (0.63**), except that the dry weight of broomrape spikes (g/m^2) (0.49*) was positively, significantly and moderately correlated. Whereas, the number of branches/plant at 60 days was negatively, highly significantly and strongly correlated with biological yield (ton/fed) (- 0.62**) and seed yield (ton/fed) (- 0.61**). The data in the same Table (3) cleared that the root length (cm) at 60 days was positively, significantly and strongly correlated with biological yield (ton/fed) (0.53*) and seed yield (ton/fed) (0.50*). On the other hand, the root length (cm) at 60 days was negatively, highly significantly and strongly correlated with the number of broomrape (spikes/m^2) (- 0.55**) and the dry weight of broomrape spikes (g/m^2) (- 0.67**).

The data in Table (3) revealed that the fresh weight of root (g) at 60 days was positively, highly significantly and strongly correlated with the number of broomrape (spikes/m^2) (0.92**) and the dry weight of broomrape spikes (g/m^2) (0.90**). While, the fresh weight of root (g) at 60 days was negatively, highly significantly and strongly correlated with biological yield (ton/fed) (- 0.92**) and seed yield (ton/fed).

Results presented in Table (3) show that the biological yield (ton/fed) was positively, highly significantly and strongly correlated with the seed yield (ton/fed) (0.99**). Otherwise, the biological yield (ton/fed) was negatively, highly significantly and strongly correlated with the number of broomrape (spikes/m^2) (- 0.99**) and the dry weight of broomrape spikes (g/m^2) (- 0.98**).

The data in Table (3) cleared that the seed yield (ton/fed) was negatively, highly significantly and strongly correlated with the number of broomrape

(spikes/m^2) (- 0.98**) and the dry weight of broomrape spikes (g/m2) (- 0.97**).
Data in Table (3) cleared that the number of broomrape (spikes/m^2) was positively, highly significantly and strongly correlated with the dry weight of broomrape spikes (g/m^2) (- 0.97**).

Table (2): Mean performance of some faba bean genotypes under naturally infested soil conditions by broomrape for traits: plant height (cm), number of branches/plant, root length (cm), fresh weight of root (g) (at 60 days), biological yield (ton/fed), seed yield (ton/fed), number of broomrape (spikes/m2) and dry weight of broomrape spikes (g/m2) in the 2018/19 season.

Genotypes (G)		Season 2018/19 – Traits: Plant height (cm) at 60 days	Number of branches/plant at 60 days	Root length (cm) at 60 days	Fresh weight of Root (g) at 60 days	Biological yield (ton/fed)	Seed yield (ton/fed)	Number of broomrape (spikes/m^2)	Dry weight of broomrape spikes (g/m^2)
Sakha 1	(G_1)	78.72	3.00	15.19	71.28	2.829	0.628	32.50	71.32
Giza 843	(G_2)	92.83	2.40	15.89	64.37	3.639	0.985	17.00	50.98
Giza 716	(G_3)	72.95	2.85	13.73	79.64	1.707	0.244	61.00	94.67
Nubaria 1	(G_4)	72.39	4.15	13.12	83.96	1.495	0.176	66.50	95.06
Misr 3	(G_5)	87.64	2.35	15.35	65.83	3.590	0.964	18.50	52.65
Assiut 62	(G_6)	83.51	2.30	14.57	68.88	2.797	0.623	33.00	72.44
Assiut 85	(G_7)	81.35	2.20	12.52	73.84	2.648	0.591	38.50	76.82
Assiut 115	(G_8)	83.11	2.30	13.28	70.36	2.744	0.614	36.00	72.89
Assiut 125	(G_9)	80.27	2.15	11.65	74.50	2.548	0.578	40.50	81.32
Assiut 215	(G_{10})	77.65	2.80	11.12	77.80	2.403	0.546	45.00	84.51
LSD 5% for: (G)		6.649	0.469	2.371	4.412	0.164	0.063	6.128	7.584

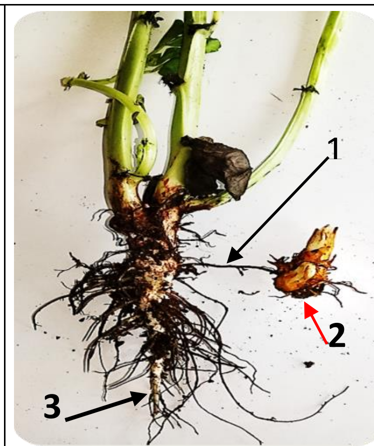
Table (3): Correlation coefficient among the studied traits in the 2018/19 season.

Traits	Season 2018/19 – Correlation coefficient: Plant height (cm) at 60	Number of branches/plant at 60 days.	Root length (cm) at 60	Fresh weight of Root (g) at 60	Biological yield (ton/fed).	Seed yield (ton/fed).	Number of broomrape (spikes/m^2).	Dry weight of broomrape spikes (g/m^2).
Plant height (cm)	–	–	–	–	–	–	–	–
Number of branches/plant	- 0.53*	–	–	–	–	–	–	–
Root length (cm)	0.59**	0.06 n.s	–	–	–	–	–	–
Fresh weight of Root (g)	-	0.71**	- 0.50*	–	–	–	–	–
Biological yield (ton/fed).	0.92**	- 0.62**	0.53*	- 0.92**	–	–	–	–
Seed yield (ton/fed).	0.92**	- 0.61**	0.50*	- 0.90**	0.99**	–	–	–
Number of broomrape	-	0.63**	-	0.92**	- 0.99**	- 0.98**	–	–
Dry weight of broomrape	-	0.49*	-	0.90**	- 0.98**	- 0.97**	0.97**	–

V. Broomrape infection and parasitism stages on the faba bean plants

The images show the stages of broomrape infection and parasitism on the faba bean plants, as well as the damage they inflict, which were taken throughout the experiment and during the stages of preparing the samples to take the anatomical sections of the secondary roots for the faba bean genotypes.

Figure (1): The images show the stages of broomrape infection and parasitism on the faba bean plants in the 2018/19 season.

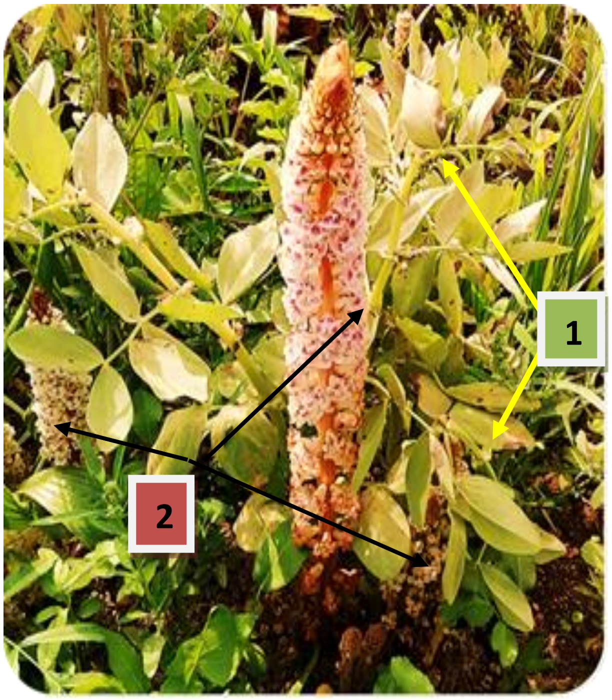


Picture **(A)**	Picture **(B)**	Picture **(C)**
This picture shows the young tubercle of broomrape at the beginning of parasitism on the secondary root of the faba bean plant of the genotype **Giza 716**, after 60 days of planting.	The number **(1)** in pictures **B** and **C** refers to the secondary root that was penetrated by the broomrape, while the number **(2)** refers to the young tubercle of the broomrape. The number **(3)** in the picture **C** refers to the main root of the faba bean plant.	

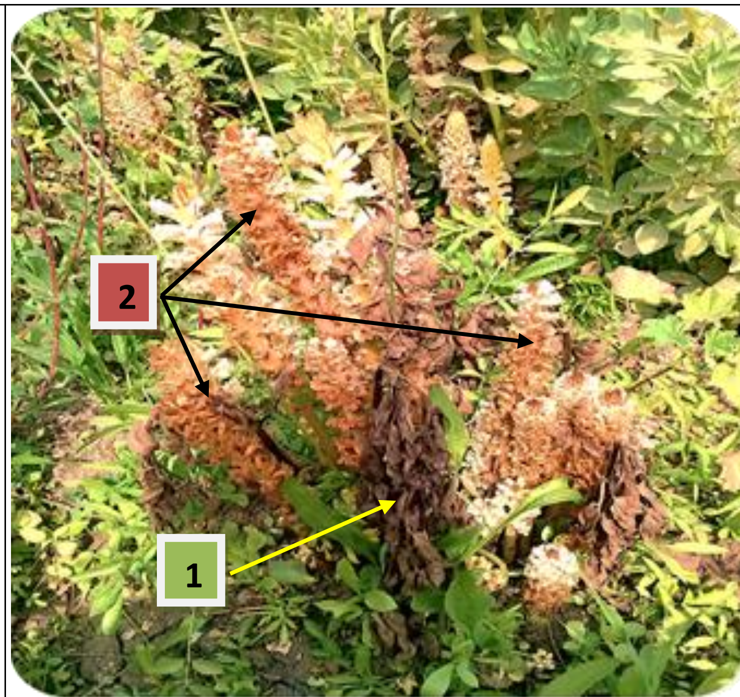
Figure (2): The images show the stages of broomrape infection and parasitism on the faba bean plants in the 2018/19 season.

Picture **(D)**

Picture **(E)**



Picture (F)

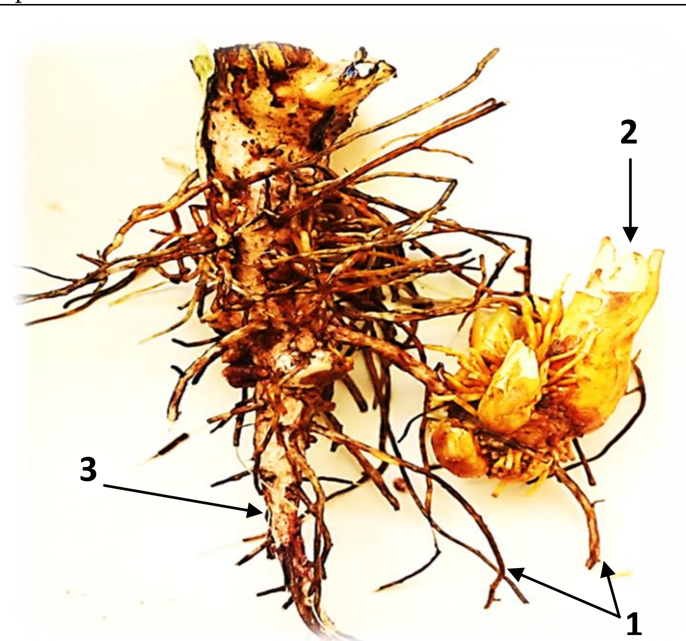


Picture (G)

- These pictures **D, E, F** and **G** show the young broomrape spikes on the roots of the faba bean plant of genotype **Nubaria 1** (Highly susceptible to broomrape infection), as well as their development and growth with age, which reveals stress and wilt **(**Picture **F)** on the host faba bean plant, with the severity of the infection causing them to dry out and die as shown in picture **(G)**.
- The stressed (host) faba bean plants are represented by number **(1)**, while the (parasite) broomrape spikes are represented by number **(2)**.

Figure (3): The stage after the stimulation and germination of the broomrape seeds, with the beginning of parasitism on the secondary roots of the faba bean plant.

Picture (H)



Picture (I)

- Genotype **Giza 716**, a faba bean plant with **<u>a normal root</u>** . - The number **(1)** in the picture **H** refers to the main root of the faba bean plant, while the number **(2)** refers to the secondary roots.	- Genotype **Giza 716**, a faba bean plant with **<u>an infected root</u>** , after 60 days of sowing. - The number **(1)** in picture **I** refers to the secondary root that was penetrated by the broomrape, while the number **(2)** refers to the young tubercle of the broomrape. - The number **(3)** in the picture **I** refers to the main root of the faba bean plant.

Figure (4): The stage after the stimulation and germination of the broomrape seeds, with the beginning of parasitism on the secondary roots of the faba bean plant.

Picture **(J)**

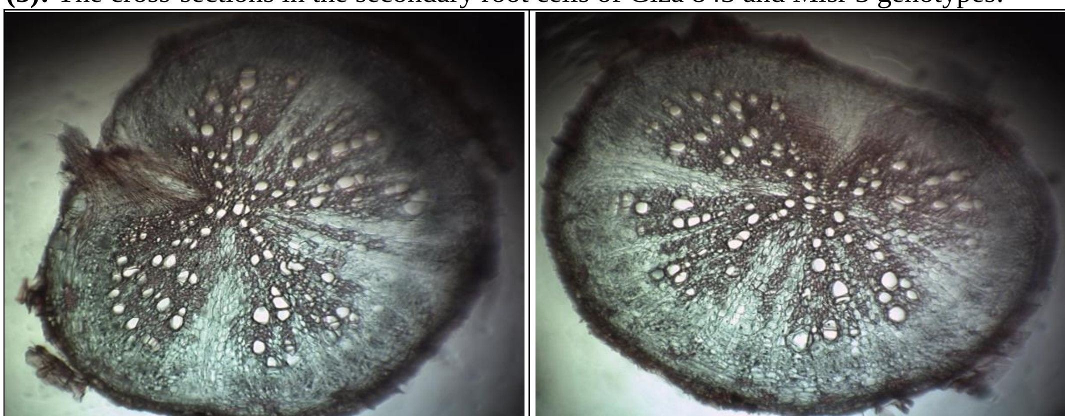
- Genotype **Nubaria 1** (Highly susceptible to broomrape infection), a faba bean plant with **<u>an infected root</u>** , after 60 days of sowing.
- The numbers **1, 2** and **3** in picture **J** indicate the young tubercle of the broomrape that penetrated the faba bean plant's secondary roots.

Looking at the previous pictures in the Figure (1, 2, 3 and 4), we could be summarizing the following:

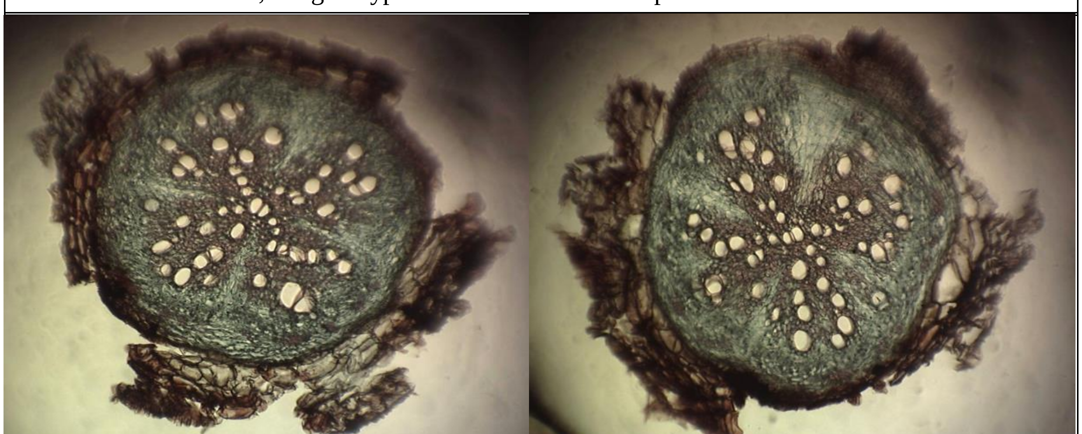
Broomrape seed germination occurs only in response to a chemical signal from the host root. Before germination, broomrape seeds must undergo conditioning under suitable temperature and moisture conditions in the soil. Following the conditioning phase, the seed produces a "germ tube" or radicle in response to a chemical stimulant from the host root, as shown in pictures (C, I and J). Several factors influence the germination of broomrape in the soil, including temperature, moisture, osmotic stress, pH, nutrients, soil type, and stimulants produced by host plants. After germination, the radicle elongates by cell division and extension and attaches to host roots mainly in the region of root elongation and absorption, as shown in picture (J). The tip of the radicle enlarges (tubercle) as soon as it attaches to the host. After 1 to 2 weeks of growth, a shoot bud develops on the tubercle, producing a flowering spike which elongates and emerges above the soil, as shown in pictures (J, D, E and F). Broomrape obtains carbon, nutrients, and water through haustoria that connect the parasite to the host vascular system, as shown in picture (J). Broomrape infestations cause an extensive reduction in crop yield and adversely affect crop quality, as shown in pictures (E, F and G). Such findings are in general agreement with those obtained by Kadry and Tewfic (1956), Abou-Raya et al. (1973), Aber and Sallé (1983) and Nandula (1998).

VI. The cross-sections of the secondary root cells for some faba bean genotypes.

Figure (5): The cross-sections in the secondary root cells of Giza 843 and Misr 3 genotypes.

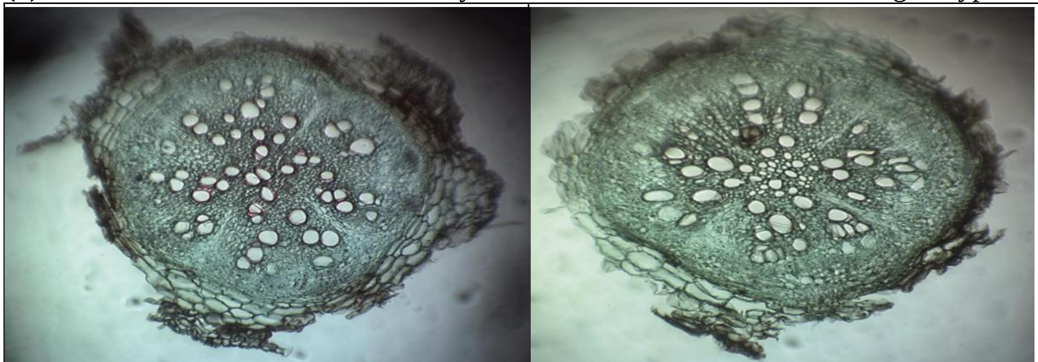


Giza 843, the genotype is **tolerant** to broomrape infection - normal

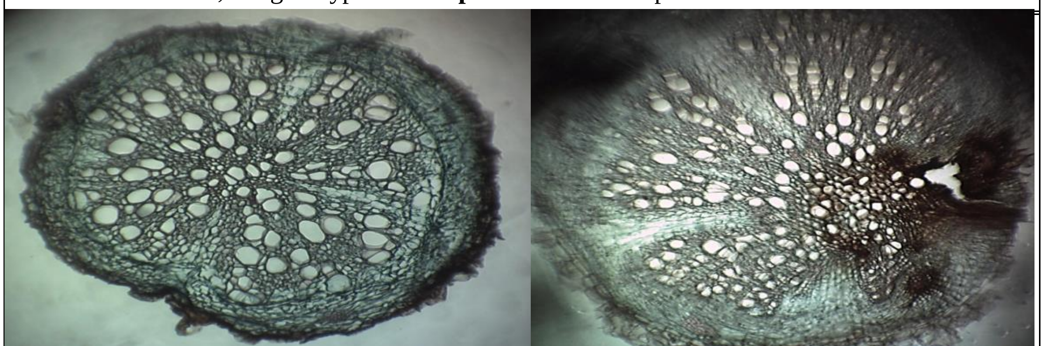


Misr 3, the genotype is **tolerant** to broomrape infection - normal

Figure (6): The cross-sections in the secondary root cells of Sakha 1 and Giza 716 genotypes.

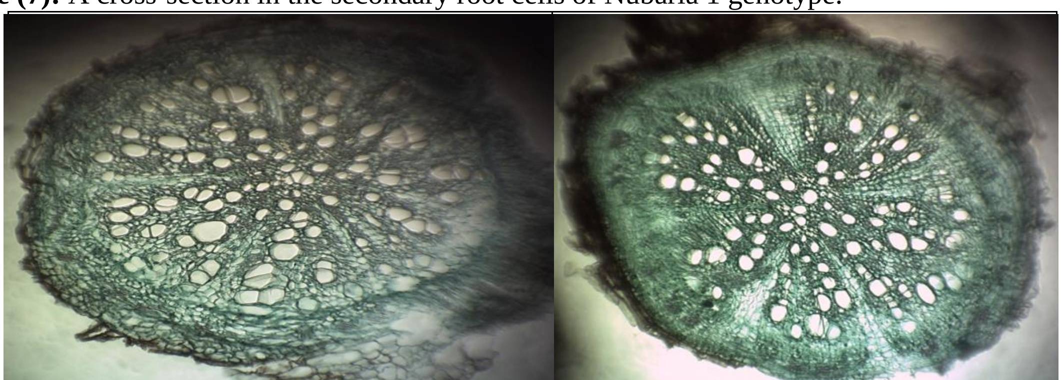


Sakha 1, the genotype is **susceptible** to broomrape infection **-** normal

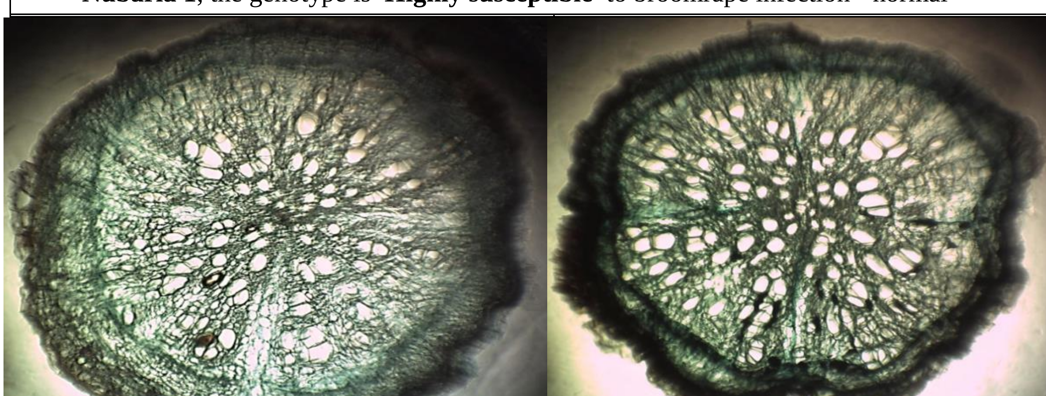


Giza 716, the genotype is **susceptible** to broomrape infection **-** normal

Figure (7): A cross-section in the secondary root cells of Nubaria 1 genotype.

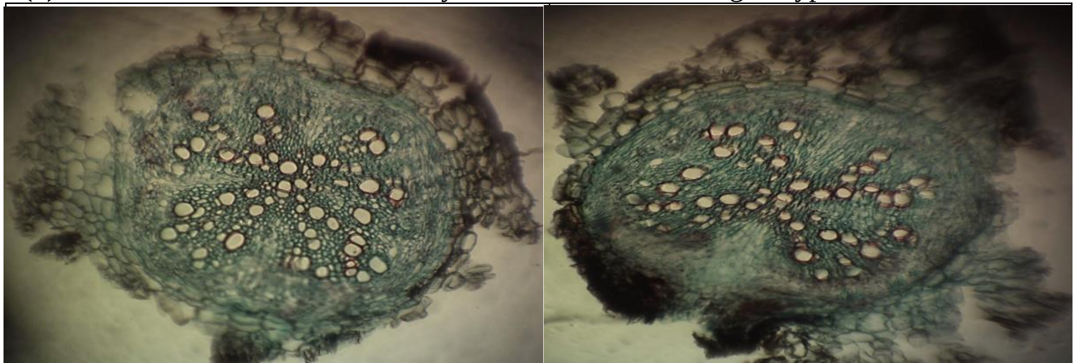


Nubaria 1, the genotype is **Highly susceptible** to broomrape infection **-** normal

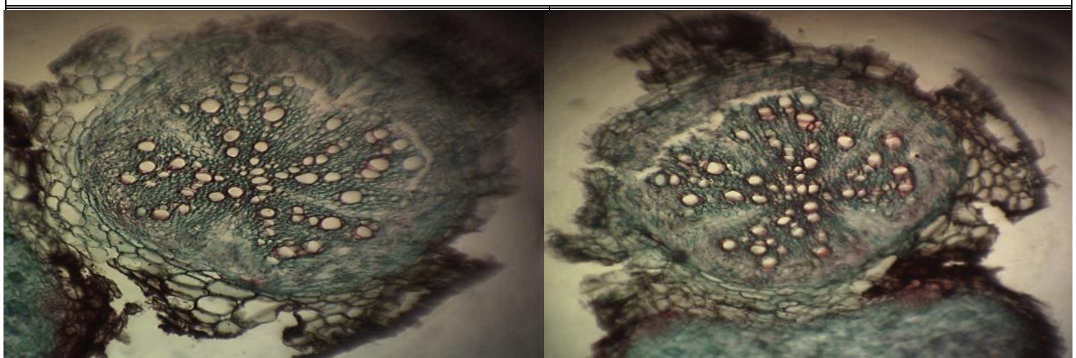


Nubaria 1, the genotype is **Highly susceptible** to broomrape infection **-** infected

Figure (8): A cross-section in the secondary root cells of Assiut 62 genotype.

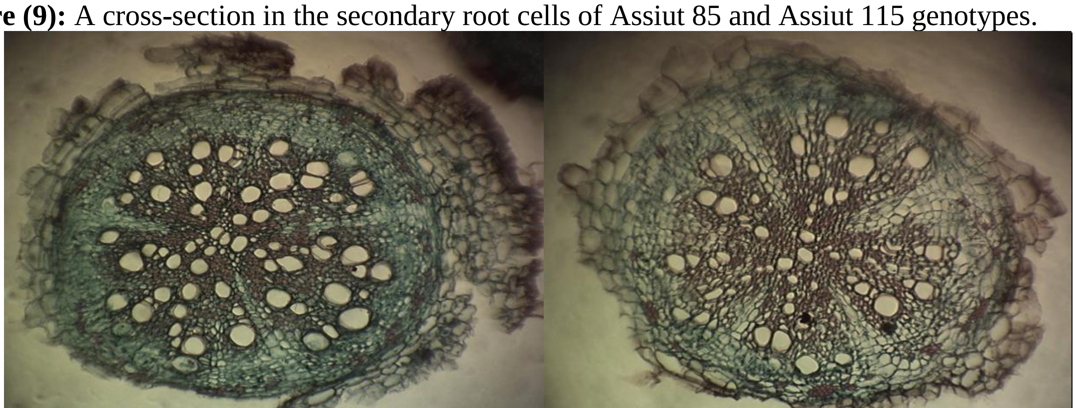


Assiut 62, the genotype is **susceptible** to broomrape infection **-** normal

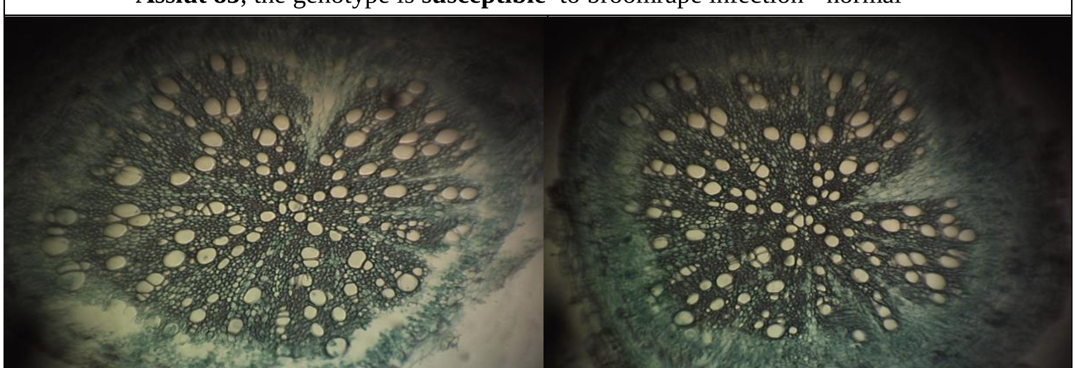


Assiut 62, the genotype is **susceptible** to broomrape infection - infected

Figure (9): A cross-section in the secondary root cells of Assiut 85 and Assiut 115 genotypes.

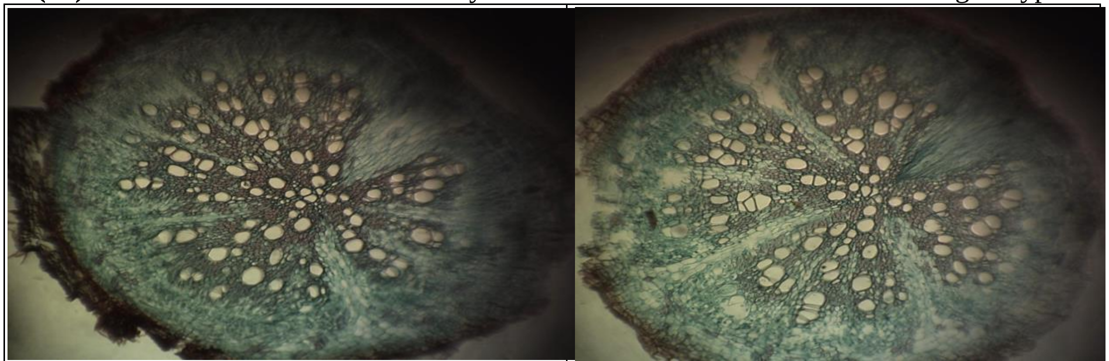


Assiut 85, the genotype is **susceptible** to broomrape infection **-** normal

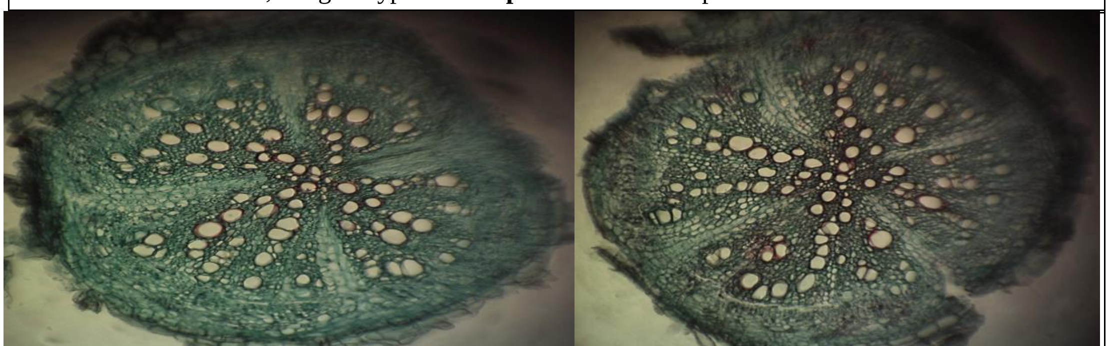


Assiut 115, the genotype is **susceptible** to broomrape infection **-** normal

Figure (10): A cross-section in the secondary root cells of Assiut 125 and Assiut 215 genotypes.



Assiut 125, the genotype is **susceptible** to broomrape infection **-** normal



Assiut 215, the genotype is **susceptible** to broomrape infection **-** normal

We may conclude the following from the cross-sections of the secondary root cells for some faba bean genotypes shown previously in the Figure (5, 6, 7, 8, 9 and 10):

The vascular system in faba bean root cells may play a key role in broomrape infestation tolerance. In normal cases, genotypes' root cells include interstitial spaces that allow water, nutrients, and metabolites to flow between various parts of the plant. In the case of broomrape infection, it thickened the root cells wall of the tolerant genotypes and nearly fully blocked the interstitial spaces of their roots (stamping) to prevent water and photosynthetic products of the plant from reaching the parasite. These findings suggest that the vascular system of cultivars Giza 843 and Misr 3 root cells played a significant role in the tolerance of broomrape infestation compared to other susceptible genotypes to broomrape infection, such as genotype Giza 716 and the highly susceptible genotype Nubaria 1. It's worth noting that xylem occlusion in tolerant genotypes might be a reaction of the young parasite to these barriers, that is, the excretion of more anchoring glue and possibly also enzymes at the infection site could lead to the activation of xylem occlusion, another defence mechanism that might cause tubercle necrosis. The present results are confirmed with those obtained by Pe´rez-de-Luque *et al.* (2005), Abbes *et al.* (2006), Pe´rez-de-Luque *et al.* (2007), Pe´rez-de-Luque *et al.* (2010), Abdel-Wahab and Eman (2021).

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الملخص العربي

أداء بعض الطرزالوراثية للفول البلدى لتحمل الإصابة بحشيشة الهالوك

أبو بكر عبد الوهاب أحمد طنطاوى[1] ،صفوت شلبى عبد الله[2]، ياسر أحمد محمد حفنى [2] وأحمد رشاد محمود رضوان[2]

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أجريت تجربة ميدانية في مزرعة البحوث الزراعية بالكوثر، كلية الزراعة، جامعة سوهاج خلال موسم 2018/19 ، هدف هذا البحث لتقييم أداء بعض الطرز الوراثية للفول البلدى وكذلك دراسة بعض الصفات الجذرية المورفولوجية والتشريحية لتحديد الطراز الوراثي الأكثر تحملاً للإصابة بالهالوك تحت ظروف العدوى الطبيعية للتربة بالهالوك. تم استخدام تصميم القطاعات الكاملة العشوائية فى ترتيب قطع الأرض مع إستخدام ثلاثة مكررات. شملت التجربة 10 طرز وراثية من الفول البلدى (سخا 1 ، جيزة 843 ، جيزة 716 ، النوبارية 1 ، مصر 3 ، أسيوط 62 ، أسيوط 85 ، أسيوط 115 ، أسيوط 125 ، أسيوط 215). أوضحت النتائج المتحصل عليها أن كلا من الطراز الوراثي جيزة 843 ومصر 3 أظهرا تحملاً أكبر وبشكل ملحوظ للإصابة بالهالوك من الطرز الوراثية الأخرى حيث سجلوا أقل قيم لعدد الهالوك (الشماريخ/م^2) والوزن الجاف لشماريخ الهالوك (جم/م^2). علاوة على ذلك ، أنتج الطراز الوراثي جيزة 843 و الطراز الوراثي مصر 3 أعلى محصول بيولوجى ومحصول بذرى (طن/فدان) تحت هذه الظروف من العدوى الطبيعية للتربة بالهالوك. بينما كان كلا من الطراز الوراثي النوبارية 1 و جيزة 716 معرضين بشدة للإصابة بالهالوك وسجلا أعلى قيم لعدد الهالوك (الشماريخ/م^2) والوزن الجاف لشماريخ الهالوك (جم/م^2) ، وقد أعطوا أيضًا أقل القيم للمحصول البيولوجي ومحصول البذور (طن/فدان) تحت هذه الظروف. كما أظهرت نتائج البيانات المتحصل عليها بخصوص معامل الارتباط بين الصفات المدروسة أن صفة طول الجذر كان لها إرتباط إيجابي معنوي قوي مع المحصول البيولوجي والمحصول البذرى (طن/فدان). من ناحية أخرى ، كان لهذه الصفة إرتباط سلبى معنوي قوي بعدد شماريخ الهالوك والوزن الجاف لشماريخ الهالوك. أما بخصوص صفة الوزن الطازج للجذر كان هناك إرتباط إيجابي معنوي قوي مع عدد شماريخ الهالوك والوزن الجاف لشماريخ الهالوك. بينما كان لهذه الصفة إرتباط سلبى معنوي قوي مع المحصول البيولوجي والمحصول البذرى (طن/فدان). تشير النتائج إلى أن نظام الأوعية الناقلة بخلايا الجذر للطرازين جيزة 843 و مصر 3 قد لعب دورًا مهمًا في تحمل الإصابة لغزو الهالوك مقارنة بالطرز الوراثية الأخرى المعرضة للإصابة بالهالوك مثل الطراز الوراثي جيزة 716 الحساس للإصابة والطراز الوراثى النوبارية 1 الشديد الحساسية للإصابة بالهالوك. أخيرا يمكننا أن نستنتج أنه تم اكتشاف العديد من آليات الدفاع في نباتات الفول البلدى المتحملة للإصابة بالهالوك ، والتي تتضمن بشكل أساسي تقوية جدار الخلية وختم الأوعية الناقلة لخلايا الجذور مع انخفاض في إفراز المواد المنبهة لإنبات بذور الهالوك .